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General Cardiovascular Magnetic Resonance Imaging

1. Anatomic and functional cardiovascular magnetic resonance imaging (CMR) requires:

- A. Ability to perform long breath-holds (>15 s)
- B. Weight <100 kg (220 lbs)
- C. Sinus rhythm
- D. Absence of coronary stents
- E. Claustrophobia management

Correct answer is E.

CMR imaging no longer requires prolonged breath holding [1]. Patients of up to 230 kg (400 lb) may be imaged, although image quality may be suboptimal in the morbidly obese [2]. The presence of regular sinus rhythm is desirable for cardiac imaging but not mandatory. Stents cause local image artifacts but are not contraindication for CMR [3–5]. Claustrophobia management is essential before CMR is attempted.

2. In comparing CMR with other noninvasive imaging modalities, which of the following statements is correct?

- A. The exposure to ionizing radiation with CMR is more than with a single chest X-ray, but considerably less than that of a chest computed tomography (CT) scan
- B. The exposure to ionizing radiation with CMR is more than with a Tc-99m myocardial perfusion single-photon emission computed tomography (SPECT) study, but considerably less than that of a TL-201 planar study
- C. Because of high spatial and temporal resolution, CMR is better than echocardiography for evaluation of small and highly mobile structures
- D. Because of the ability to perform volumetric imaging with high spatial and temporal resolution, CMR is the “gold standard” for measurement of ventricular volumes, mass, and ejection fraction
- E. Coronary calcium detection is much better with CMR than with a multidetector CT (MDCT) scan

Correct answer is D.

CMR has no associated ionizing radiation exposure at all. CMR allows for volumetric imaging in any orientation and offers high spatial and temporal resolution. Measurements of right and left ventricular volumes, mass, and ejection fraction are highly accurate and reproducible, establishing CMR as the reference standard for these quantities [6–9]. CMR is not particularly good for evaluation of small and highly mobile structures (e.g., valve leaflets, vegetations, etc.), because the high resolution CMR requires ECG gating for acquisition of the entire image data set over several cardiac cycles. Highly mobile structures may not be at exactly the same position in several cardiac cycles and, thus, misregistration may occur, with subsequent image blurring. X-ray imaging (fluoroscopy and CT) are much better than CMR in visualizing coronary calcifications [10].

3. Which of the following statements comparing CMR with other noninvasive imaging technologies is correct?

- A. Clinical CMR can image the coronary arteries with superior spatial resolution compared with 64-detector MDCT
- B. Clinical CMR cine functional imaging has higher temporal resolution than M-mode echocardiography
- C. CMR is better than transthoracic echocardiography in assessing valvular structure
- D. Flow measurements by CMR are more reliable than those from transthoracic echocardiography in assessing calcific aortic valvular stenosis
- E. Flow measurements by CMR are more reliable than those from transthoracic echocardiography in assessing aortic valvular insufficiency

Correct answer is E.

The in-plane spatial resolution of clinical CMR for coronary artery imaging is typically $1 \times 1 \text{ mm}^2$, with a slice thickness of 1.5 to 2.0 mm [11]. Current 64-row MDCT technology can achieve imaging with isotropic voxels of $0.4 \times 0.4 \times 0.4 \text{ mm}^3$ [12]. However, CMR temporal resolution still remains better than that of MDCT. On the other hand, the temporal resolution of echocardiography (and particularly M-mode) is even higher (typically 1–5 ms) [13]. CMR is unproven for assessing small structures that are rapidly moving (such as the cardiac valves or vegetations). CMR flow measurements are not always accurate for assessing the severity of valvular stenosis, because there are limitations on the phase encoding of high flow velocities [14]. CMR flow measurements are very accurate for quantitative measurement of valvular regurgitant lesions and compare favorably to semiquantitative echocardiographic data [15–17].

4. For which of the following applications CMR is not the gold standard?

- A. Evaluation of anomalous coronary arteries
- B. Assessment of infarcted myocardium
- C. Measurement of left ventricular ejection fraction
- D. Measurement of right ventricular end-diastolic volume
- E. Assessment of coronary atherosclerosis

Correct answer is E.

CMR has been validated in phantom, experimental animal, and human studies as the most accurate technique to measure left and right ventricular volumes and ejection fraction [6, 7, 9, 18]. CMR can also visualize the origin and proximal course of the coronary arteries and is better than (or at least equivalent to) conventional contrast X-ray angiography for assessment of coronary anomalies [19, 20]. Cardiac CT with contrast enhancement can also accurately visualize the coronary anomalies, but the associated contrast load and X-ray radiation exposure may not be appropriate for younger patients. Delayed contrast-enhanced CMR can accurately assess the infarcted myocardium, with excellent correlation with pathology data [21–23]. CMR is still not able to reliably visualize coronary atherosclerosis and, therefore, cannot be considered the gold standard for this indication.

5. In a patient with atrial fibrillation and wide variability of the RR interval, who is undergoing CMR, which of the following statements is correct?

- A. The left ventricular ejection fraction cannot be measured
- B. The measured left ventricular ejection fraction grossly overestimates the systolic performance
- C. The measured left ventricular ejection fraction correlates well with invasively measured values
- D. The left ventricular mass cannot be measured
- E. The myocardial viability cannot be assessed

Correct answer is C.

With significant RR variability, the diastolic period varies among different cardiac cycles. Systole, on the other hand, occurs usually at approximately 250 to 300 ms from the QRS complex and is less dependent on the heart rate than is diastole [24]. In a cine CMR study, the first phase to be obtained (starting on the QRS complex) is the end diastole. Systole and early diastole can be imaged and, thus, the end-diastolic volume and mass can be accurately measured. The end-systolic volume may be expected to slightly underestimate the actual systolic ventricular performance, because it will be the average of cycles with low(er) systolic performance occurring at cycles after a short RR interval (decreased preload, Frank Starling's law) with cycles with high(er) systolic performance occurring at cycles after long RR cycles (increased preload). Accordingly, the measured left ventricular ejection fraction may slightly underestimate the actual systolic performance. Despite these theoretical considerations, one study that specifically investigated measurements of left ventricular volumes and ejection fraction with prospective ECG-gated CMR and invasive contrast ventriculography in 26 patients with atrial fibrillation did not find significant discrepancy between the two methods [25]. Myocardial viability can be assessed both with delayed enhanced images (timed at systole) or with low-dose dobutamine administration, which will demonstrate the anticipated augmentation of systolic function, if viability is present.

6. Which of the following patients should not be assessed with CMR?

- A. A 46-year-old patient with severe congestive heart failure, orthopnea, tachycardia, and low oxygen saturation (89% on a 100% O₂ face mask)
- B. A 70-year-old patient with moderately severe aortic regurgitation, considered for aortic valve surgery
- C. A 10-year-old patient with coarctation managed with an aortic stent 2 years ago

- D. A woman with exertional syncope
- E. A patient with coronary artery disease and severe left ventricular systolic dysfunction (ejection fraction 20%) who is being considered for revascularization

Correct answer is A.

The patient described in option A is unstable and likely to not tolerate supine positioning required for CMR. CMR is an appropriate test to quantitatively assess aortic regurgitation and precisely quantify left ventricular volumes and aortic dimensions [15–17, 26]. CMR is also appropriate for assessment of patients with coarctation [27, 28]. In the woman with exertional syncope, CMR can exclude the presence of hypertrophic cardiomyopathy, assess for anomalous coronary arteries, and evaluate for arrhythmogenic right ventricular dysplasia or other myocarditis/cardiomyopathies. Finally, CMR is an appropriate test to assess for the presence of myocardial viability in patients with severe left ventricular dysfunction considered for revascularization [18, 21].

7. A 25-year-old patient is referred for CMR. As soon as he is placed in the scanner, he becomes diaphoretic, his pulse increases to 160 beats per minute, and he complains of nausea and lightheadedness. The most appropriate approach would be to:

- A. First place a peripheral intravenous line and then proceed with the study as planned
- B. Administer a mild sedative (e.g., a short acting benzodiazepine) orally, place nasal prongs for supplemental oxygen, and then proceed with the study
- C. Stop the study. Administer oxygen via nasal cannula and immediately obtain a medical evaluation of the patient and, if needed, a 12-lead ECG
- D. Stop the study. Discharge the patient to home with instructions to contact his physician
- E. Ask the patient if he is willing to proceed with the study, and if the patient agrees, proceed as planned

Correct answer is C.

Hemodynamic instability is a contraindication for CMR imaging. This patient may have had a panic attack inside the CMR scanner, but medical causes of the tachycardia and possible hypotension (lightheadedness, diaphoresis, and nausea) have to be evaluated and addressed as needed. Presumptive treatment for anxiety would be inappropriate, as would be discharging the patient to home without appropriate medical evaluation and treatment.



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